International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-9, Issue-3; Mar, 2022
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.93.30

Design of a Robotic Vehicle with Real-Time Video Streaming

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Received: 1 Jan 2022,

Received in revised form: 13 Mar 2022,

Accepted: 20 Mar 2022,

Available online: 30 Mar 2022

***Keywords*— Radio Frequency, Remote control, Robotic vehicle, Surveillance, video streaming**

***Abstract*— The paper presents design of a robotic vehicle with real-time video streaming. Prior to advancements in technology, military personnel and wild life researchers were used for these tasks (Intelligence gathering, Surveillance and Reconnaissance), and would risk injury and possible death to accomplish them. The need for safer means of performing these surveillance operations have become a pressing need over the years. Hence, this work aimed at developing a Robotic Vehicle capable of providing real-time video surveillance for military and wild life research operation applications. The Robotic Vehicle is made up of radio frequency based remote control, a PWM-enabled motor driver IC for efficient mobility, an OV2460 camera, and ESP32-CAM with Wi-Fi enable for video streaming without internet connection. The ESP32-CAM also serves as a web server which can be accessed by any device's browser connected via Hotspot setup. The robotic vehicle tested successfully and communicates effectively with remote control unit on the average of 0.5km distance.*

I. INTRODUCTION

The world of control is an exciting field that has exploded with new technologies where the Internet of Things vision becomes a reality. Today, IoT with AI is used to make applications such as intelligent transportation, smart security, and smart home. The wireless communication technique is beneficial in IoT nowadays [1]. Robotics and automation is the field which has made lot of impacts on industrial as well as household applications from last few decades. The reason behind the wide use of robotics is its ability to make changes in previously made systems and also it is time consuming [2]. It is crucial to ensure proper surveillance for the safety and security of people and their assets. The development of an aerial surveillance system might be very effective in catering to the challenges in surveillance systems. Current systems are expensive and complex. A cost-effective and efficient solution is required, which is easily accessible to anyone with a moderate budget. In aerial surveillance, quad copters are equipped with state-of-the-art image processing technology that captures detailed photographs of every object underneath [3]. During war, military people enter uncharted territory where they would sometimes become victims of surprise enemy attack. This robotic vehicle would be a method to trace out the enemies and use that information to make a tactical move. It is having all the necessary accessories to trace enemies like: long range camera which captures and live streams the video to the control station, sensors to detect the presence of human being and GPS/GPRS system to determine and transmit the position of the enemy targets. The system can substitute the solider in border to provide surveillance as well for reconnaissance circumstances [4].

II. REVIEW OF RELATED WORKS

In [5], an IoT Based Surveillance Robotic Car Using Raspberry PI was developed. The robot car was equipped with necessary sensors and controlled over the internet. Smart Surveillance Robot for Real-Time Monitoring and Control System in Environment and Industrial Applications presented in [6]. Their robot system called InterBot 1.0 was equipped with long-range communication system via 2.4 GHz 6-channel remote and also short range via HC-05 (Bluetooth module). The Results show the efficiency of Interbot 1.0 in monitoring real-time environments. A Hand Movement Controlled Robotic Vehicle with Wireless Live Streaming Feature was Designed and implemented in [7]. Their robot system comprised of the transmitter, the receiver and the live streaming section. Live streaming was successfully achieved by interfacing a common network (Wi-Fi), a laptop, Raspberry pi, and two software (Virtual Network Computing (VNC) and Foundation Internet Nouvelle Generation (FING)) together to ensure the surveillance feature for the user.

In [8], Surveillance robot to monitor the work performance in hazardous area was developed. Their robot was embedded with sensors for identifying any obstacle and human via Wi-Fi and provides live streaming to the Admin. The robot is operated over Wi-Fi using Bynk App Software. Web-based Application for Mobile Robot using IoT Platform was developed in [9]. The Web application based processed commands are transmitted to the control unit of the robot through Wi-Fi and this robot controlled through web application via mobile phone.

In [10], an embedded Mobile Robot for Surveillance Applications was developed. Their mobile robot was connected wirelessly via a low power ZigBee module to the control station. This allows the operator control the mobile robot motions and monitoring the physical events in the operating environment. During testing, the mobile robot shows that it can run continuously for approximately 6.5 hours at a motor shaft speed of 25 rpm without need to recharge the battery.

A rover with live video transmission was implemented in [11]. The Arduino is connected to Bluetooth module through UART protocol and programmed for speed control and motion control of rover. The commands from the Arduino through Bluetooth device, controls the motion of the rover. The robotic vehicle can be used for number of applications especially in surveillance, military and security.

III. DESIGN METHODOLOY

The robotic vehicle comprises of hardware and software systems. The design approach adopted for the robotic vehicle is prototyping method for hardware implementation and agile method for software implementation. The block diagram used to achieve the aim is shown in fig.1

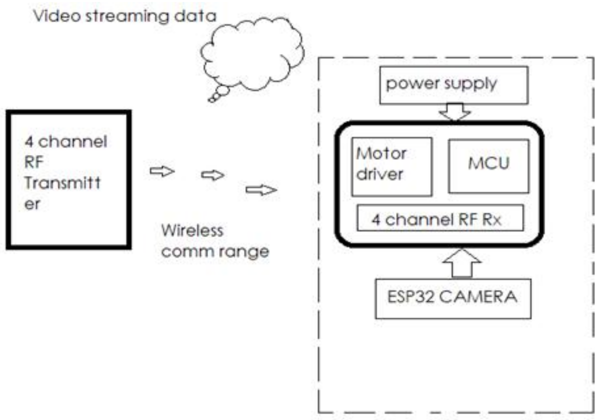

Fig.1. Block diagram of the robotic vehicle

3.1 Robot Hardware

The robot system hardware comprises of Remote Control, Microcontroller, Mobility, Visual Sensor and Streaming, and Power Supply units.

A. Remote control unit: consists of Radio Frequency (RF) transmitter and Receiver responsible for enabling unmanned control of the robotic vehicle over a long distance. The maximum distance the robot can communicate with the remote controller is 0.5km. The communication frequency of the robot is calculated using equation 1.

$$D = 10^{\frac{(P_L - 32.44 - 20 \log f)}{20}} \quad (1)$$

Where: D = Distance (km); P_L= Maximum Path Loss (dBm); f = Frequency (MHz)

Maximum Path Loss (P_L) is calculated using equation 2

P_l = Transmit power-receiver sensitivity + gains – losses - fade margin (2)

Finally, the remote control frequency calculated is 425.647MHz for communication with robot.

B. Microcontroller: is basically for processing signals and controlling each component to function optimally. The Receiver unit of the Radio Frequency remote module is interfaced with the microcontroller unit. This is done because Radio Frequency module alone cannot achieve the mobility model required to drive the robotic vehicle. This mobility type is possible through Pulse

Width Modulation (PWM); signals that activate variable speed control in the Motor Driver IC. For this purpose, an 8-bit Microcontroller, which is capable of generating the required PWM signal is required.

C. Mobility unit: is the part of the robotic system responsible for the movement of the vehicle. It comprises of the Motor Driver IC and the 5V DC motors. The Arduino Uno Microcontroller sends instruction to the Motor Driver Module, which control the mobility of the robot. Signals sent by the 4 channel RF module to the Microcontroller provide the microcontroller with information necessary to driving the Mobility unit. The 4 channels of the RF module basically enable the controller drive the mobility unit to the left, right, forward and reverse.

D. Visual Sensor and Streaming unit: is responsible for taking the visual sensory data in form of pictures and videos that would be necessary to navigate the surveillance robot remotely. The main aim of this unit is to achieve wireless streaming of video data without internet connectivity. For this to be possible, this unit requires camera module (for visual capture implementation), microcontroller (for processing the captured images or videos), and communication module (for data transmission between the robot and the user. The flow chart used to achieve this module is shown in fig.2.

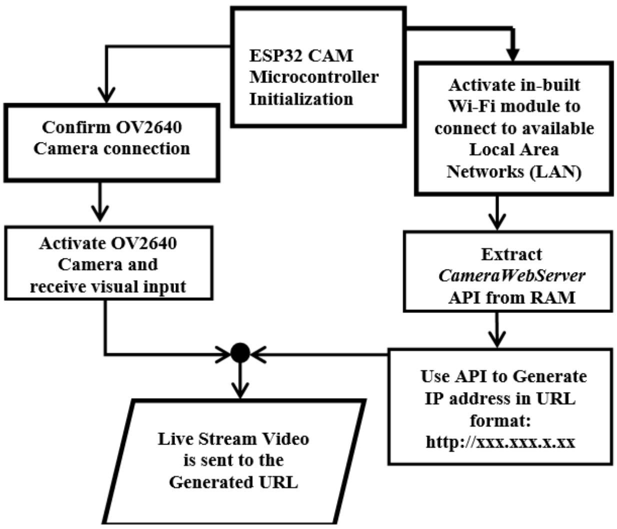

Fig.2: Flow Chart for Visual Sensing and Video Streaming

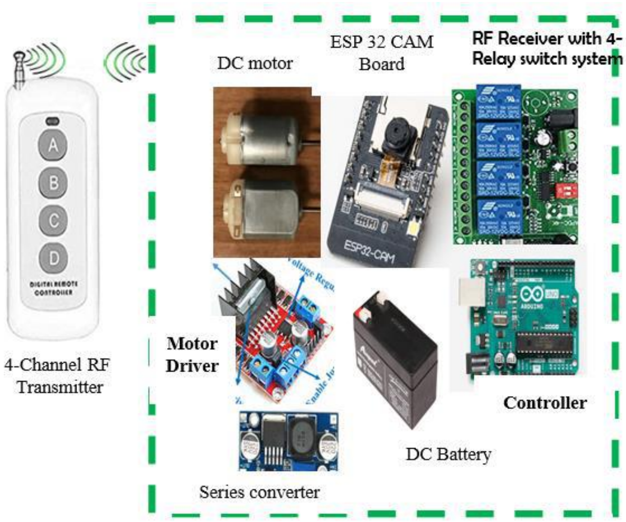

Fig. 3: Robotic Vehicle System

E. Power Supply: The system is powered by a 12V 1.3 Ah DC Battery which supplied required voltages to various components of the robotic vehicle. It was chosen because of its maintenance-free, valve regulated, long service life, deep discharge recovery and resistant to high temperature.

However, the robot system hardware diagram representing various components used is shown in fig.3.

3.2 Robotic Vehicle Software

The Tool used for programming microcontrollers is Arduino Integrated Development Environment (IDE). It is a cross-platform application that is written in functions from C and C++. The Arduino IDE (fig.4) is where the codes that serve as the intelligence of the system are written, compiled and sent to the Arduino Uno board as well as the ESP32 CAM. The programing language is embed C.

3.3 RF Transmitter and Receiver Operation and Circuit Diagrams

The RF module consists of a transmitter and a receiver, which are easily installed and integrated into any embedded system design and employs an 8-bit code for their function. They are reprogrammable; the receiver possesses a "learn" button from which a previous code can be deleted and another code can be uploaded or "learned". The maximum range of the module in free field is 200m. This is the effective maximum range of the transmitter signal under optimal conditions, or in the open field with free line of sight. However, with an antenna, the range can be increased to over 500m. The circuit diagram for the Transmitter is shown in fig.5.

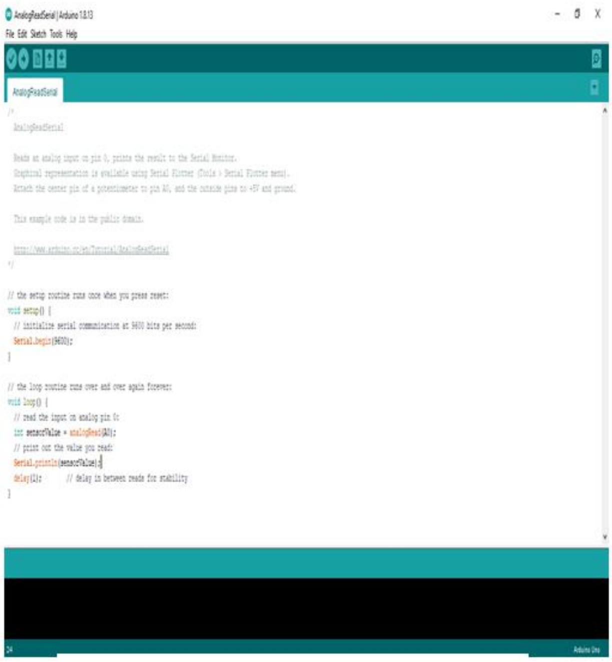

Fig.4: Arduino IDE for Robot coding

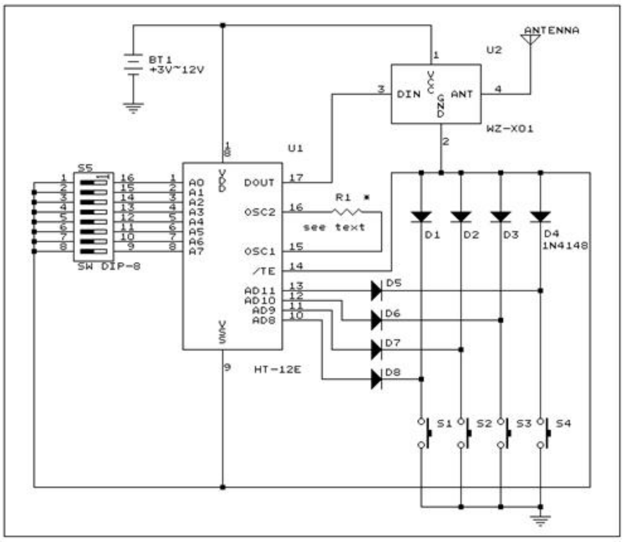

Fig.5. Remote control transmitter of the robotic vehicle

In receiver unit (fig.6), the U1 receives and decodes the data from the transmitter. Then it compares the input date with its local addresses for any match. After that, it runs an error check to determine if there is any unmatched code. If no unmatched code is found, the input data is transferred to the D8~D11 pins. As a result, the VT pin is set to a HIGH state indicating a successful data transfer. The U1 output controls the 4 PNP transistors, which are connected differently to the 4 relays. Anytime S1-S4 switches are engaged, the TE pin is switched low, as a result, the encoder chip U1 and the transmitter module U2 are powered and then the encoder scans and transmits the status of the 12 Bits address and the data serially. Four Relay channels are coupled with the Receiver section and the section is designed to drive a 4-point relay output. This output can then be used to control DC and AC devices, which in this case will be the input pins of the Arduino Uno microcontroller. The clamps on the Relay devices are NO / NC (normally open / normally closed).

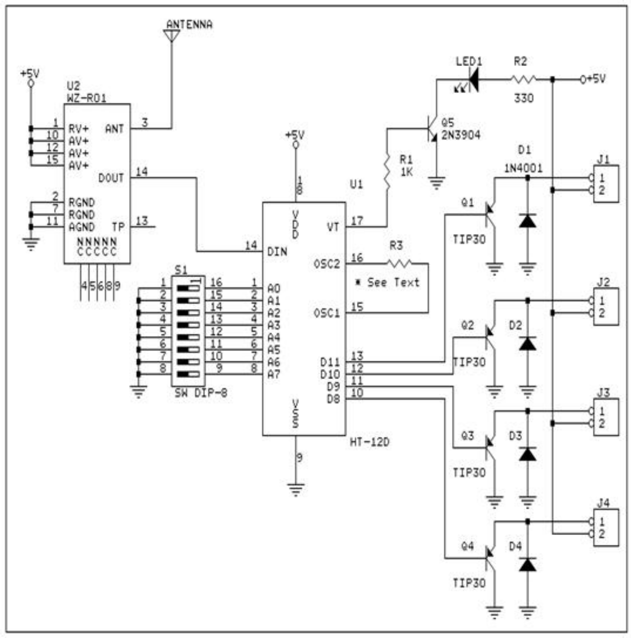

Fig.6: RF Receiver’s unit

3.4 Remote control coding and Flow Chart

Embed C programming language used in writing the codes in Arduino IDE platform. The 4-Channel RF module initiates whatever decision microcontroller takes. The microcontroller executes action to effect motor driver that controls the wheels. The sequence of operations starts from the RF module to the Arduino Uno, to the motor driver and finally, to the wheels. The flow chart used to actualize the remote control and mobility coding is shown in fig.7.

3.5 Microcontroller Firmware Algorithm

The firmware code is the program that drives the microcontroller board. The firmware code of the designed system was written following these steps:

Step 1: Execute Single loop run-time process
Step 2: Ask or wait for remote input
Step 3: Is there Remote input?
Step 4: If No, go back to step 2; if yes, go to step 5
Step 5: Check which button was pressed
Step 6: Check how the button was pressed; Long press or short press

Step 7: If long press, go to 8; if short press go to 9

Step 8: Call up function/process assigned to short press of a particular button input remote.

Step 9: If TTL (Transistor-Transistor Logic) protocol is ON, activate streaming at a static IP address.

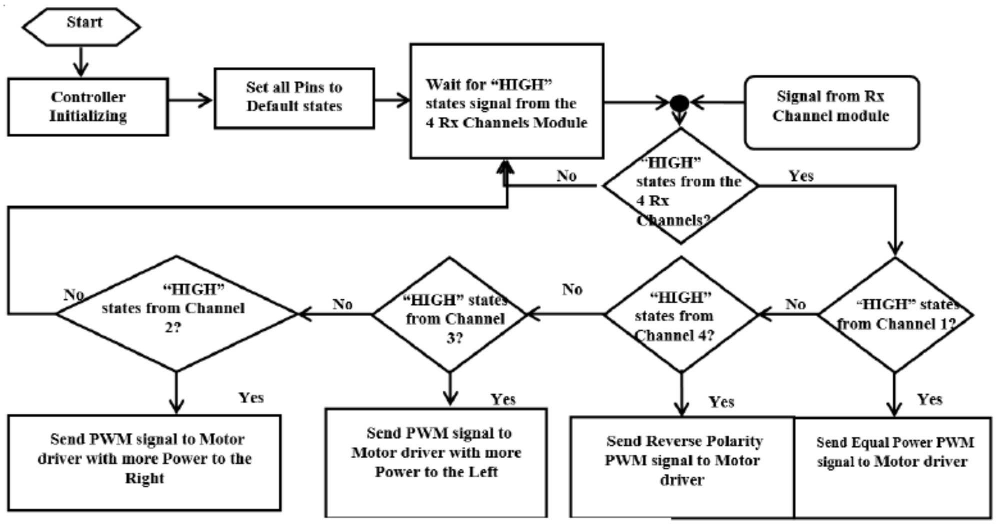

Fig.7: Remote control and Mobility flow chart

3.6 Simulated circuit of the Robot system in PROTEUS

The robot system was simulated using PROTEUS software as shown in fig.8.

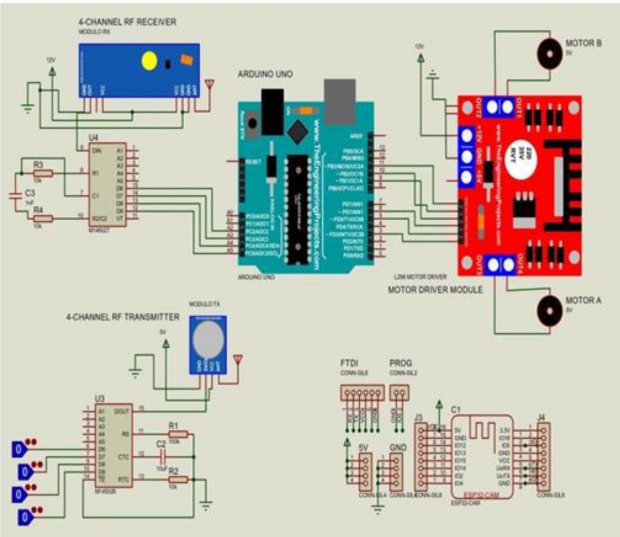

Fig.8: Robot System simulated in PROTEUS

The complete built real time robot for video streaming is shown in fig.9.

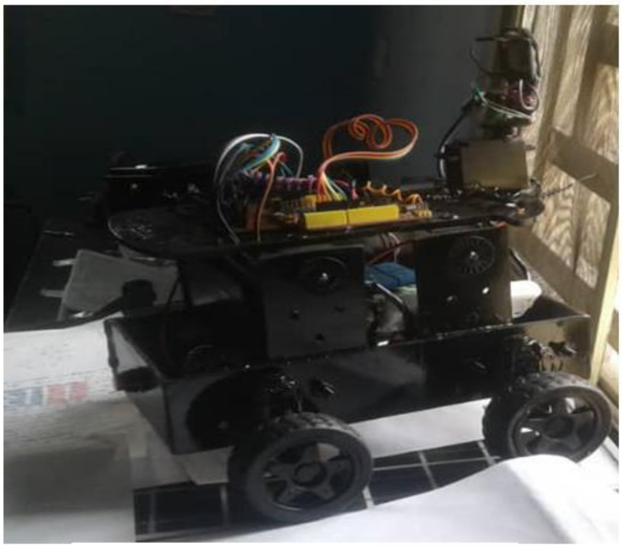

Fig.9: The picture of the robot system

IV. RESULTS OBTAINED

4.1 Remote Control Distance Test

Before the system is coupled, the remote sensing module was tested to ensure that all four channels are in good working condition. The four channel 433MHz RF module has an inbuilt reliability test to ensure that it is in proper working conditions. The Receiver module has an inbuilt LED, which is connect to the four channels. When a Channel button is pushed on the Transmitter module, the corresponding LED is turned ON. The diagram for the set is shown in the Fig. 10.

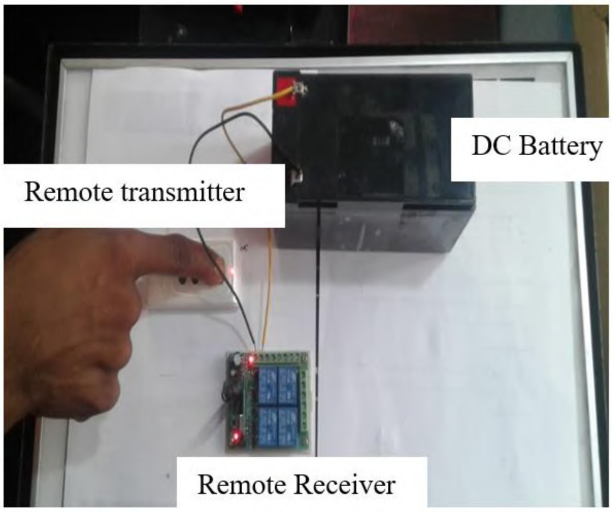

Fig.10: Remote control test diagram

Table 1: Test Results for the motor driver IC setup

Robotic Vehicle Motion Models	Wheel Configuration			
	Multi-meter Readings for each wheel: Voltage (V)			
	Right 1	Right 2	Left 1	Left 2
Forward motion	4.95	0	4.97	0
Reverse motion	0	4.89	0	4.91
Right Turn	2.45	0	4.95	0
Left Turn	4.98	0	2.37	0

4.2 Mobility Test

The mobility test was done to determine the effectiveness of the motor driver IC deployed to perform the mobility operation. The four output pins of the Motor Driver Module were read with a multi meter to ensure that the switching operation was done accurately. The common terminal of the multi meter was placed on the ground pin of the Arduino Uno microcontroller, and the signal terminal connected to the output pins of the motor driver IC as shown in fig.11.

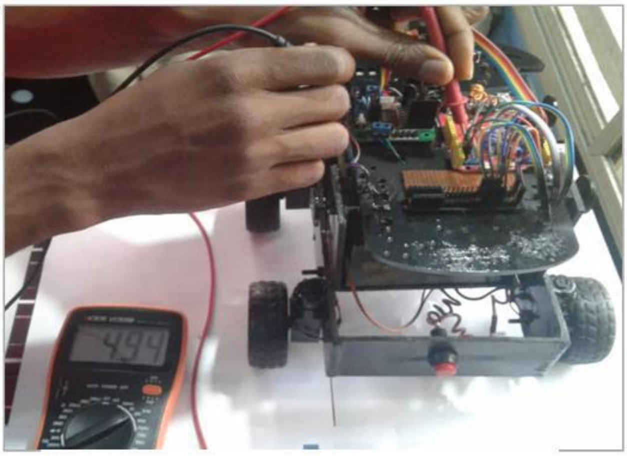

Fig.11: Multi-meter reading of motor driver IC

After reading, table 1 shows each wheel voltage of the robot on the forward, reverse, right and left motion.

4.3 ESP32 setup & Wi-Fi connectivity test

The Arduino IDE was configured to be compatible with the ESP32 CAM board for effective code upload. The IDE was configured by installing a JSON file in the "Additional Board Manager URLs" field located in the "preferences" section's dialogue box. The Wi-Fi configuration code was uploaded to the board through Local Area Network (LAN) setup. The ESP32 board runs the Wi-Fi code successfully which automatically connected to the LAN. The code block screen shot of the successful test is shown in fig.12.

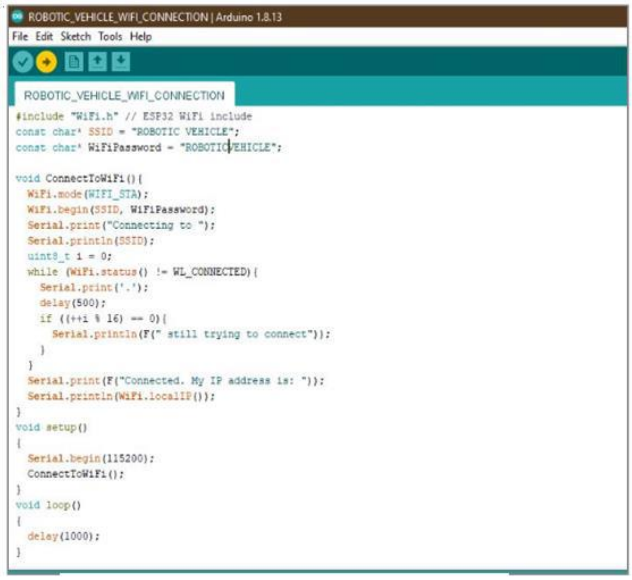

Fig.12: Wi-Fi tested connection code

4.4 ESP32 CAM board camera test

The ESP32 CAM board camera was tested also. The IP address of the robotic vehicle changes as network disconnection and reconnection. This was not seen as a problem because the system alerts the control station (connected phone or laptop) to the change and sends the new IP address. The web video streaming and camera streaming setup is shown in fig.13.

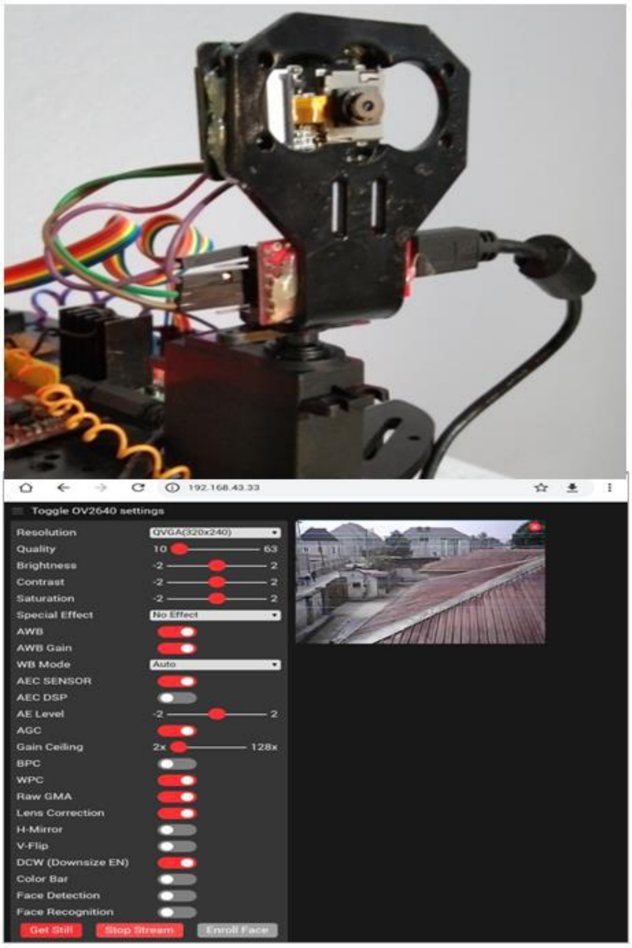

Fig.13: Video streaming and Camera streaming setup

V. CONCLUSION

The design of a robotic vehicle with real-time video streaming is implemented and tested. The developed robot system is capable of taking video of any suspicious event and sends the video footage via Wi-Fi to the operator's smart phone for further action. The remote unit is responsible for sending signals to the robot system. The control signals are sent by the microcontroller to the mobility unit which consists of H-bridge, PWM-enabled Motor driver IC, and the motor driver IC that controls the wheels according to the military motion model adopted in the system operation. This model gives the robotic vehicle four (4) modes of movement: forward motion, right turn motion, left turn motion, and reverse motion. The visual sensing and streaming unit is responsible for visual data of the Robotic vehicle. This unit is driven by the ESP32 CAM; a 32-bit Wi-Fi enabled IoT board which has an OV2460 camera with about 2 megapixel quality and more than 30fps. The power unit of the system is 12V DC which caters for all the electronic components on the system except the ESP32 CAM which required 5V. The system was designed to communicate effectively with remote control distance of 0.2km and could go as far as 0.5km in a Line-of-Sight operation. The ESP32 CAM served as a web server, enabling the video to be accessed over a Uniform Resource Locator (URL) which can be accessed from anywhere in the world with internet connection. To further enhance on the robotic system, solar cell can be deployed as means of charging the battery and control mechanism established to ensure smooth steady operation of the robot at any given time.

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